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GONDOLA SYSTEM FOR HELICOPTER TRANSPORT OF EXTERNAL CARGO

Brooks & Perkins, Inc.
12633 Inkster Road
Livonia, Mich. 48150

September 1977

Final Report for Period November 1975 - June 1977

Approved for public release;
distribution unlimited.

Prepared for

APPLIED TECHNOLOGY LABORATORY
RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT*

During previously conducted research and development effort (Technical Report 74-91, "Design Concepts for Helicopter Pallets and Gondolas"), a conceptual design was developed for a gondola system that exploited the potential/improved utilization of the helicopter's external cargo carrying capabilities. The program reported herein includes the research and development effort to update and revise that gondola conceptual design, incorporating applicable airdrop and modular aerial delivery platform technology. During this effort, two experimental gondola systems were fabricated and assembled, and static and ground tests were conducted to demonstrate performance requirements. Results of this contract provide two identical experimental gondola systems that will be subjected to operational suitability and Force Development Testing and Experimentation evaluations.

The conclusions and recommendations contained in this report are concurred in by this Laboratory.

Mr. S. G. Riggs, Jr., Military Operations Technology Division, served as Project Engineer for this effort.

*On 1 September 1977, *after this report had been prepared*, the name of this organization was changed from Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory to Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM).

9 Final rept. Nov 75-Jun 77

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 18 USAAMRDL TR-77-28 19	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 GONDOLA SYSTEM FOR HELICOPTER TRANSPORT OF EXTERNAL CARGO.		5. TYPE OF REPORT & PERIOD COVERED Nov 1975 - June 1977 Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s) 15 DAAJ02-76-C-0007 New
9. PERFORMING ORGANIZATION NAME AND ADDRESS Brooks & Perkins, Inc. 12633 Inkster Road Livonia, Michigan 48150		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ~~62209A~~ 1F262209AH76 00 17 ~~141 EK~~ 16
11. CONTROLLING OFFICE NAME AND ADDRESS Applied Technology Laboratory, U.S. Army Research & Technology Laboratories (AVRADCOM) Fort Eustis, Virginia 23604		12. REPORT DATE 11 September 1977
		13. NUMBER OF PAGES 39 12 41p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Helicopters
Cargo
Material Handling Vehicles
Containers
Container Handling Devices
Sling Loads

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers the design, the development and the static testing of 8x8x10- and 20-foot gondolas. The technical feasibility and performance data provided will permit further study of the transportation of these systems by helicopter. The maximum gross weights of the 10- and 20-foot units are 15,000 and 30,000 pounds respectively. The structure has a rigid, porous floor; an open superstructure; and ISO corner fittings. It is designed to be acquired and released by container handling devices or handled by next page

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20. forklifts. The gondola system is intermodal and consists of a basic center unit (8x8x20 feet) and two end units (8x8x10 feet) that are all modules that can be coupled to make 8x8x40-foot and 8x8x20-foot assemblies.

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INTRODUCTION

BACKGROUND

The functional mission of existing and planned Army cargo helicopters is to provide a safe and efficient means for transporting cargo. In order to take advantage of the helicopter's full potential for carrying external cargo, more effective means should be developed for handling cargo and vehicles than slings and nets. An earlier study, reported in Reference 1, generated a concept and a design for a gondola system that exploits the helicopter's external cargo carrying potentials. This investigation demonstrated that gondolas of two sizes could be coupled to develop the full payload capacity of the CH-47, the CH-54 and HLH helicopters. This study suggested that certain areas be studied more in order to produce a system that would not have the negative aerodynamic factors associated with present-day equipment. The proposed gondola is compatible with American National Standard Institute (ANSI) and International Organization for Standardization (ISO) geometry and can be transported with slings or other load-acquisition equipment. The gondola may be introduced at any segment of a supply system to transport vehicles, equipment or break-bulk cargo.

PURPOSE

The objective of the work reported here was to update and refine the concept developed earlier, to make a design based on the refined concept, to construct two identical sets of gondolas, and to test these to determine whether the design satisfies certain requirements. In addition to carrying out the objectives described above, several other requirements were established for the work reported here. Each system must consist of a basic 8x8x20-foot center unit and two 8x8x10-foot end units. These units must be capable of coupling to each other to form a 20- or 40-foot unit meeting ANSI MH5.1 requirements, but the units must be capable of sustaining loads far greater than the loads the standard ANSI container of comparable size can sustain.[2] The gondola floors must be porous in order to demonstrate the improved empty flight profile predicted in Reference 1. Finally, the gondola must be capable of being acquired and

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[1] Weber, C., Young, R. DESIGN CONCEPTS FOR HELICOPTER PALLETS AND GONDOLAS, Parsons of California; USAAMRDL Technical Report 74-91, U.S. Army Air Mobility Research and Development Laboratory, Ft. Eustis, Virginia, November, 1974, AD A004013.

[2] AMERICAN NATIONAL STANDARD MH5.1-1971, The American Society of Mechanical Engineers, New York, N.Y., 1972.

released by a helicopter using a multi-hook suspension system and the container handling device (CHD).[3]

GENERAL CONCEPT

The 10- and 20-foot gondolas shown in Figures 1 and 3 are the final design configurations, which were developed from the concept recommended in Reference 1. Each has a rigid floor structure covered with a standard grating to provide a porous floor. The floor grating is secured by 3000-pound capacity tiedown rings. The ISO-type corner fittings are also used for coupling the units together and may be seen in Figure 2. The gondolas are equipped with small, portable ramps and removable tierods for loading, as shown in Figure 3. Figure 1 shows the ramps in their stowed positions and the tierods in place. Figure 4 is a view of the tierod's turnbuckle device with the folding handle. The ends of the tierods are retained with quick-release pins and are identical on the 20-foot assembly. The upper set on the 10-foot unit is 4.82 inches longer due to the geometry of the structure. Forklift tunnels are provided on the sides for handling the 10- and 20-foot units. These are designed to be used when the units are fully loaded, but there is a limit of 30,000 pounds for the 40-foot coupled assembly.

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[3]Costa, F., Nutley, W., Seebol, R., Wilson, G.; DESIGN, DEVELOPMENT AND LABORATORY TESTING OF A CONCEPTUAL HELICOPTER-TRANSPORTED CONTAINER HANDLING DEVICE, Boeing Vertol Company; USAAMRDL Technical Report 74-40, U.S. Army Air Mobility Research and Development Laboratory, Ft. Eustis, Virginia 23604, May, 1974, AD783394.

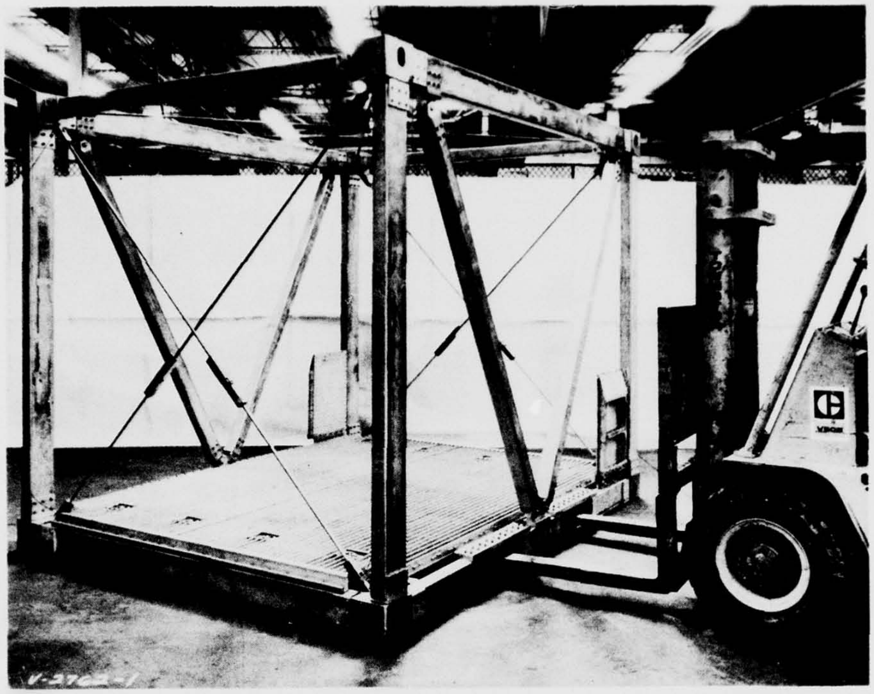


Figure 1. Ten-Foot Gondola Assembly

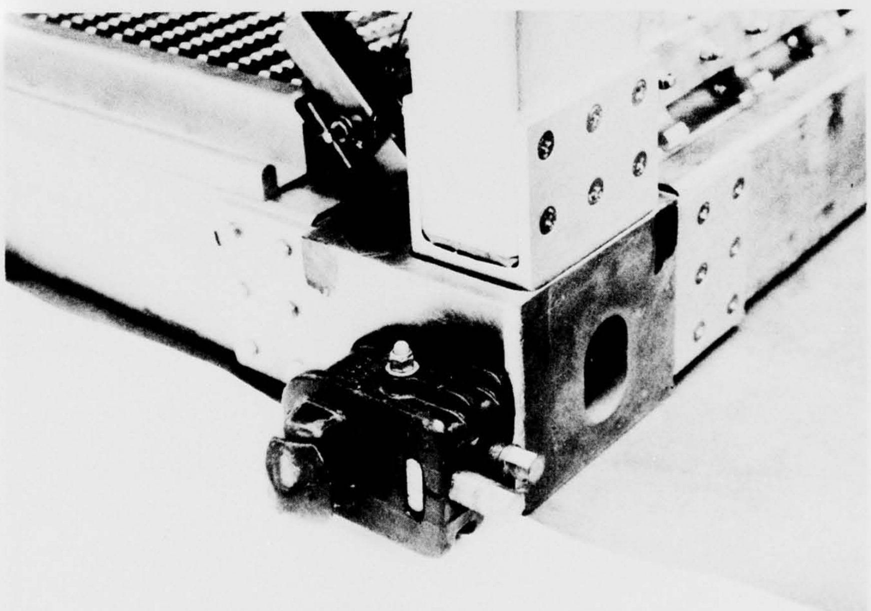


Figure 2. ISO Corner and Coupler.

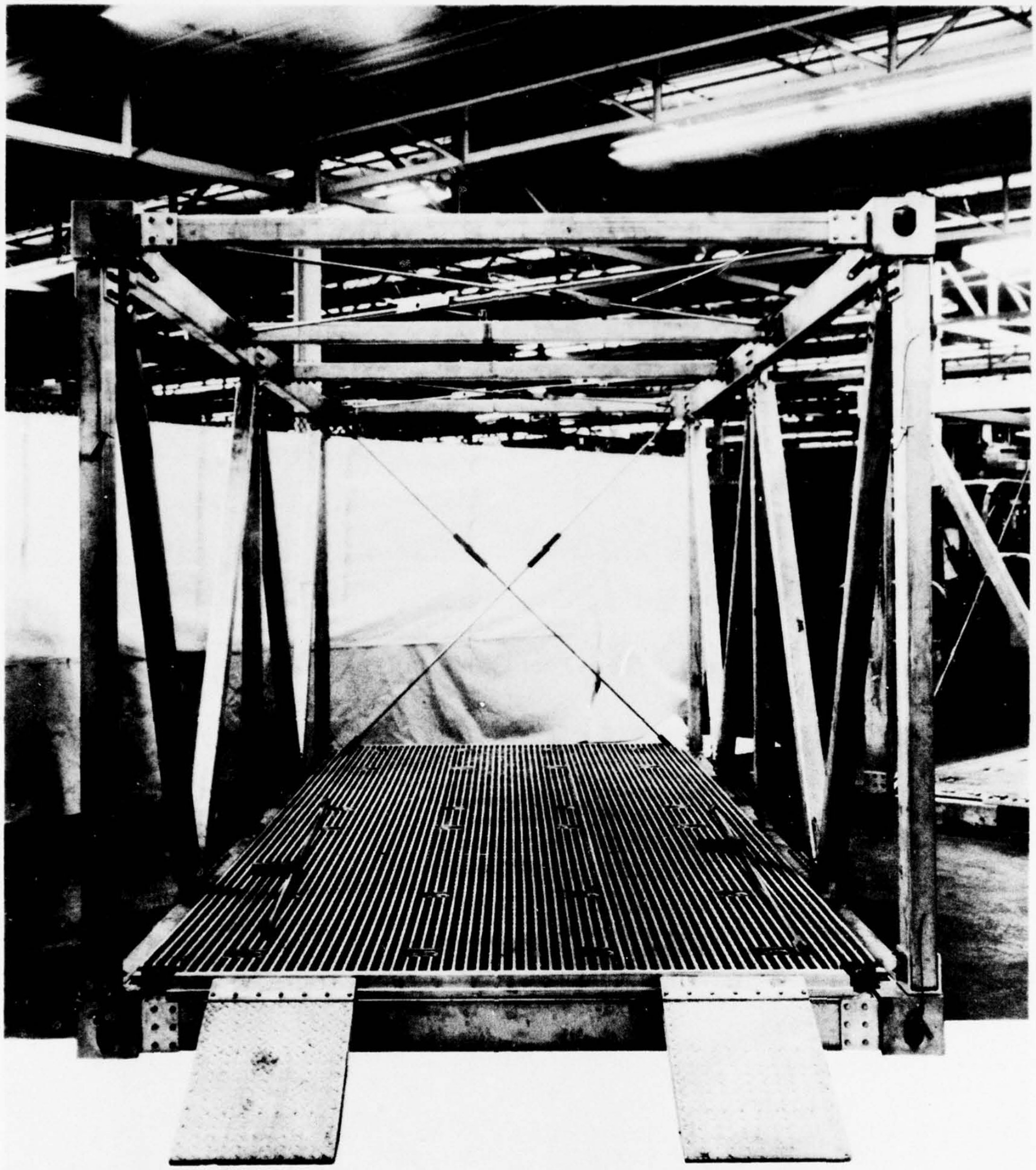


Figure 3. Twenty-Foot Gondola Assembly

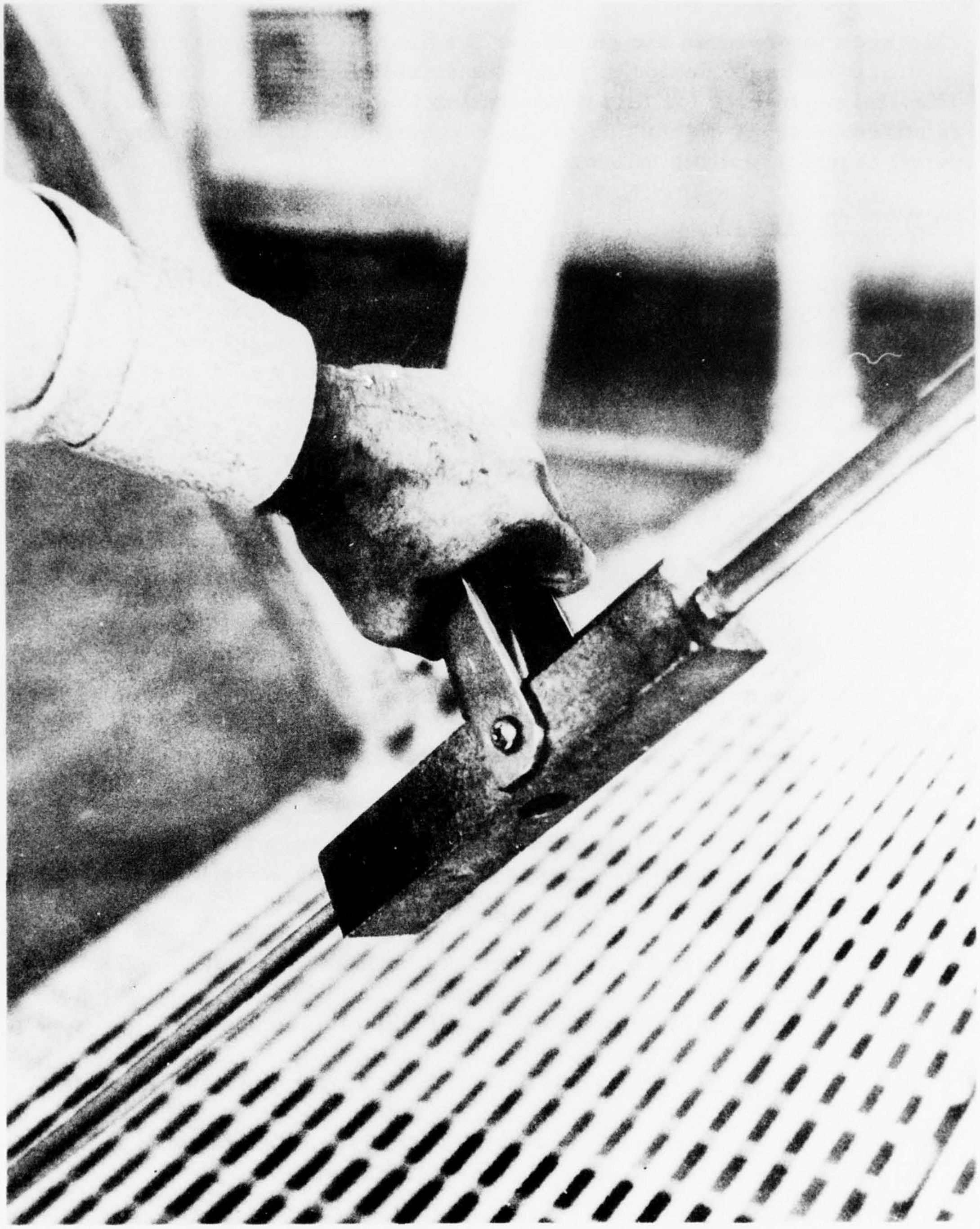


Figure 4. Turnbuckle for Tierod Adjustment

DESIGN

This section presents the results of the analytical study performed to optimize the basic design parameters established in the earlier study. The design criteria for this optimization included both ANSI and special requirements. A discussion of these requirements, the analyses and the detail design resulting follows.

DESIGN CRITERIA

The gondolas are required to conform to ANSI intermodal 8x8x10-, 20- or 40-foot dimensional requirements, as noted in Figure 5 and ANSI MH5.1.[2] The specification sets forth the basic overall dimensions that all containers must meet in order to interface with world-wide handling devices. Also, the gondolas must use standard corner fittings.

Other basic criteria for the gondolas are as follows:

1. Design gross weights:

10-foot	15,000 pounds
20-foot	30,000 pounds
40-foot	60,000 pounds

2. Suspension-point lift factors:

   Dynamic factor: 3.40 (includes 2.0g helicopter acceleration factor)
   Load asymmetry factor: 1.04
   System safety factor: 1.50

3. Must be able to be lifted from the top corners and the design shall provide for lifting by slings with angles not more than 30° from the vertical.

4. Must be able to be lifted from the bottom corners.

5. Must be capable of withstanding ANSI racking loads.

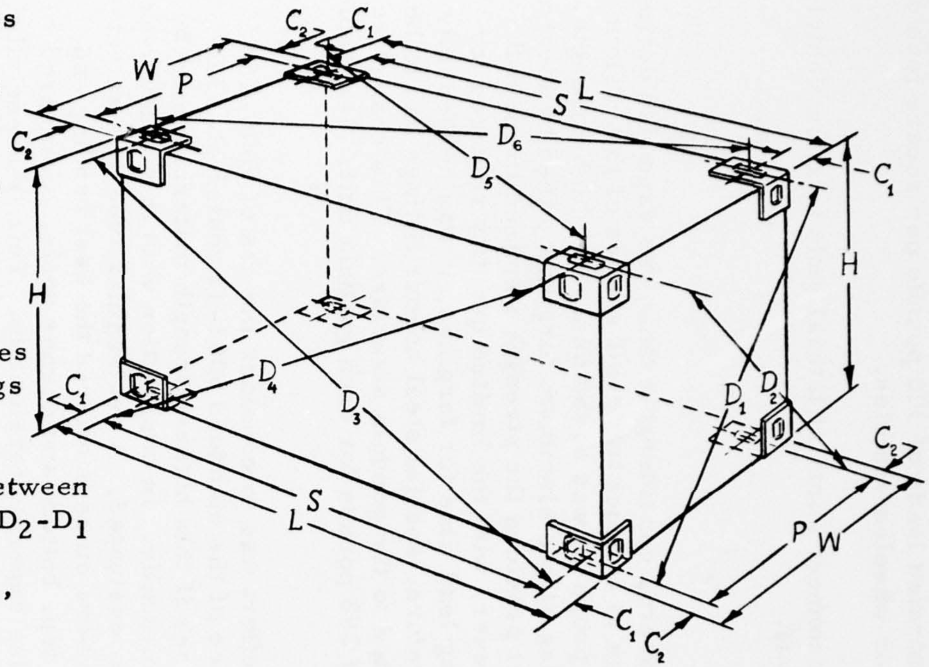
6. Must have forklift capability for both single and coupled units.

7. Must provide a load-bearing base designed to minimize in-flight instability when in the unloaded condition.

8. Must have a minimum internal width of 86.5 inches.

9. Must provide quick-acting, adjustable chocks for both longitudinal and lateral restraint.

S = Length between centers of apertures in corner fittings
P = Width between centers of apertures in corner fittings
C_1 = Corner fitting measurement: 4 +0-0.06 inches (101.5 +0-1.5 mm)
C_2 = Corner fitting measurement: 3.5 +0-0.06 inches (89 +0-1.5 mm)
L = External length of container
W = External width of container
D = Distance between center of apertures of diagonally opposite corner fittings resulting in six measurements: D_1, D_2, D_3, D_4, D_5 and D_6
K_1 = Difference between D_1 and D_2 or between D_3 and D_4; i.e., $K_1=D_1-D_2$ or $K_1=D_2-D_1$ or $K_1=D_3-D_4$ or $K_1=D_4-D_3$
K_2 = Difference between D_5 and D_6; i.e., $K_2=D_5-D_6$ or $K_2=D_6-D_5$
H = Overall height



Nominal Length	Length Overall (L)			S			P			K_1 Max.		K_2 Max.	
Feet	mm	Ft	In	mm	Ft	In	mm	Ft	In	mm	In	mm	In
40	12190 +2-8	40	0.00 +0-0.38	11985	39	3.88	2259	7	4.97	19	0.75	10	0.38
20	6055 +3-3	19	10.50 +0-0.25	5853	19	2.44	2259	7	4.97	13	0.50	10	0.38
10	2990 +1-4	9	9.75 +0-0.18	2787	9	1.72	2259	7	4.97	10	0.38	10	0.38

Width Overall (W): 8 ft 0 in +0-0.18 in (2435 +3-2 mm)
Height Overall (H): 8 ft 0 in +0-0.18 in (2435 =3-2 mm); or 8 ft 6.5 in +0-0.75 in (2600 +3-16 mm)

NOTE: Dimensions S and P are reference dimensions only. The tolerances to be applied to S and P are governed by the tolerances shown for the overall length (L) and overall width (W).

Figure 5. Assembled Corner Fitting - Diagonal Tolerances.

10. Must support concentrated loads of 300 pounds per square inch on the treadway area for wheeled vehicles.

11. Must have quick-disconnect joints at lateral ends to allow vehicles to be rolled on and off.

ANALYSIS

Since weight is a major concern, considerable time was expended during the preliminary design stage to conduct trade-off studies of the various components. The original proposal was based on a new, high-strength, ISO corner fitting, consisting of two aluminum forgings joined by electron-beam welding technique that provided the strength required to meet the top-lift requirement. However, with the limited quantity required for this program along with long lead time for forgings, it was not feasible to make these parts. Therefore, special steel corner fittings had to be developed that could be bolted to the gondola structure. This change resulted in weight increase of 298 pounds for each gondola unit. See Table 1.

Part of the analysis phase effort was to consider the use of 7005-T53 aluminum extrusions in place of the standard 6061-T6 material. All areas were investigated to see if this higher strength material could be used to reduce weight economically. In conjunction with this study, various section types were also evaluated. A rectangular tube was selected for the superstructure members since it offered the best bending and buckling properties for the top, bottom and corner posts. Compared with standard I sections, it is also superior torsionally. This is especially true in the case of the floor's longitudinal-crossmember connections. The sections selected utilizing 7005-T53 alloy were the rectangular tubes used for the floor's outer frame, the corner posts, the upper longitudinal members, the floor crossmembers and the floor grating members. These members represent approximately 80% of the structural-member weight and approximately 51% and 60% of the 10- and 20-foot total gondola weights. Each step of the stress analysis was aimed at giving the best strength to weight ratio possible. At the conclusion of preliminary design phase, the number of floor rings was considered to be excessive and was reduced, along with the 60,000-pound forklift requirement for the 40-foot coupled system.

These changes produced the final weight breakdown shown in Table 1. The weights of the gondolas were affected by the 60,000-pound gross-weight lifting capability of the heavy-lift helicopter (HLH), which required a test load of 212,000 pounds for the corner-fitting attachments. Although the 60,000-pound requirement had been dropped, the program had advanced into the procurement of material, so this requirement was not changed.

TABLE 1. GONDOLA WEIGHT BREAKDOWN

	Weight (lb) 10-Foot	20-Foot
3- x 6-inch tube	433.77	660.58
3.5- x 3.5-inch tube	153.91	350.40
*Corner castings (steel)	456.00	456.00
Channels	129.99	281.65
Grating	374.00	782.31
Tension rods	130.08	170.24
Ring and brackets	34.40	103.20
Ramp (2)	50.00	50.00
Forklift reinforcement	129.00	129.00
Bracket and hardware	50.00	100.00
Prototype weight with steel corner castings.	1,941.15	3,083.38
*Est. 158 lbs. (alum. corners).	-298.00	-298.00
Total weight with aluminum corner castings.	1,643.15	2,785.38
ACTUAL WEIGHT	1,930.00	3,040.00

If the CH-54 capability of 22,000-25,000 pounds was the limiting factor, the gondola weights could be reduced accordingly, but the use of higher strength alloys would still be required. The alloy selection is not a factor for members subject to buckling only, but those under tension or bending stress are affected by the higher strength alloys. After all testing has been completed to evaluate all the design loads and the g factors that must be sustained, a more realistic, lighter weight system may be produced.

DETAIL DESIGN

Work then proceeded in the area of detail design, such as secondary structural members, corner attachments and floor design. Also, Brooks & Perkins proposed a gondola with an inside width of 88.25 inches instead of the 86.5-inch minimum given in the Work Statement. This design goal would permit the use of 463L pallets in the future, as well as giving additional internal width for the other types of cargo. This extra width presented some problems but the final tube configuration satisfied both inside and outside requirements.

Other problem areas encountered during this phase were resolved as follows:

1. Forklift pockets: The standard 82-inch set would be provided on the 20-foot unit. The coupled 10-foot units must also meet the MH5.1 Specification (82 inches), and this was accomplished by making the pockets 14.50 inches wide.

2. Floor grating: The grating could be furnished with a serrated top surface for maximum traction or without the serrations for maximum strength. The serrated top surface was preferred and therefore selected.

3. Loads: The Work Statement required a 300-psi load capacity in the treadway areas but nowhere else. However, for simplicity, the same floor grating was used for the rest of the floor, thus giving the entire floor this load capacity.

4. Racking loads: MH5.1 does not list loads that could be applied to the gondola. The 0.6 g factor used in Reference 1 was selected.

5. Diagonals: The end diagonals must be easily removed and assembled and must be adjustable after loading. Diagonal tension rods with quick-release pins were selected as the best approach.

6. Stacking: ANSI requirements apply to both single and coupled units.

The final configurations that evolved for the 8x8x10- and 20-foot units are shown in Figures 1 and 3. The base assembly has an outer frame of 3x6-inch, 7005-T53 aluminum, rectangular tubes joined to the steel corner fittings by bolts. The floor crossmembers are 6-inch aluminum channels spaced on approximately 16-inch centers and are riveted to the side beams. These support the floor grating which is made of 7005-T53 aluminum alloy. The floor grating is secured by the cargo-ring assemblies, which are attached to the upper crossmember flanges.

The 3x6-inch tubing used for the corner posts and the upper longitudinal members are joined to the corner fittings. All of the diagonals and the upper cross beams are 3x3-inch, 6061-T6 aluminum tubing. The 0.62-inch-diameter, alloy-steel tierods are attached to the ends and to the roof sections for resisting the racking loads.

Since the 10-foot units must be capable of being connected to form a 20-foot unit also meeting ANSI requirements, a coupling device had to be provided. A standard coupler on the market, called "Tandemloc", was available that had the required strength and was selected rather than developing another coupler (see Figure 2).

The coupled gondola system is assembled as follows:

1. Loosen the two coupler bolts until the locking dogs are in their extended positions (see Figure 2).

2. Insert the couplers into the end openings of the four corner fittings with the couplers aligned squarely with the outside faces.

3. Tighten the locking-dog bolt securely.

4. Forklift the mating gondola into position and join by tightening the remaining bolts.

The tierods are removed by loosening the turnbuckle shown in Figure 4 and removing the quick-release pins. When they are reinstalled, the two rods should be tightened as a pair until approximately a 0.12-inch space appears between rod ends in the center opening of each turnbuckle. This will keep the ends square for interface with other units. All tierods should be checked after loading to assure they are snug and evenly tightened.

FABRICATION

The fabrication of the gondolas produced few difficulties. Tooling was made to drill all of the superstructure attachment holes. This included all of the longitudinal, lateral, vertical and diagonal members, and all attachment brackets. The floor crossmembers and the forklift openings were the only major members fabricated directly from the drawings. The floor grating was an adaptation of another Brooks & Perkins product and utilized the existing tooling. The designs proved to be capable of being produced without any special tools or manufacturing techniques. For any future gondolas, all members could be predrilled with the exception of the side diagonals.

The standard ISO corner fittings are steel castings designed for welding to the corner frame members. These could not be used for the gondola corners, so special fittings with larger inside cavities had to be developed (see Figure 2). These fittings, if aluminum, could have flanges for the attachment of frame members by bolting or welding. However, this could make the repair of damaged corners difficult, so we recommend the bolted connection for both the steel and the aluminum designs.

During this period, another problem surfaced: meeting the MH5.1 outside-profile requirement with the attachment fasteners. The drawings specify an MS blind lockbolt that does not extend past the outside limits. However, time did not permit this fastener to be obtained, and an alternate type had to be used.

Presently, the side diagonal members have bolted connections. A quick-release pin may be difficult to install if the gondola is resting on an uneven surface, but this may be a function of the load size and should be determined by further testing.

STATIC TESTING

The gondolas were subjected to a series of static tests that represented the most severe loading conditions they would experience. These tests were selected to represent both the ANSI and the Work Statement requirements. The dimensions were checked before and after all tests. These tests involved stacking, top lift, bottom lift and racking, and use with forklifts. The dimensional checks were performed by Brooks & Perkins, and all static testing was conducted by Miner Enterprises, Inc. of Chicago Illinois. A brief description of each test follows, with complete, detailed test data included in Appendix A. The 20- and 40-foot gondolas were loaded to the design gross weights of 30,000 and 60,000 pounds respectively. These weights were then multiplied by the appropriate load factors and also by the 1.04 load asymmetry factor for the top and the bottom lifts to arrive at the total load force required.

DIMENSIONAL CHECK

Before any testing was conducted, the gondolas were inspected dimensionally. This check was to verify conformance to the basic ANSI requirements for intermodal containers. After all static testing was completed, they were rechecked. The results of these two inspections are in Table 2.

STACKING

The six-high stacking requirement was simulated by loading one upper corner of the 20-foot gondola with a hydraulic cylinder. The downward force of 67,500 pounds (30,000 pound gross weight times 5 containers times the 1.8 load factor divided by 4) was applied and held for 5 minutes.

TOP LIFT

The top-lift requirement called for a single-point-type suspension with a sling angle of 30° from the vertical. This required the standard vertical lifting setup to be modified to produce the correct force vectors in the upper corner fittings. Figure 6 shows the test setup for simulating this condition. The 40-foot gondola was loaded with concrete blocks that weighed approximately 1300 pounds each and palletized steel bars that weighed approximately 3000 pounds each. The total gross weight, 212,160 pounds (60,000 pounds times the 3.4 lift factor times the 1.04 asymmetry factor), was then applied by four hydraulic cylinders, one located at each corner.

The test was later repeated with the standard twist-lock fitting in the upper corner opening. Figure 7 shows the fitting used to provide the vertical corner lift.

TABLE 2. DIMENSIONS OF GONDOLAS BEFORE AND AFTER TESTING

Gondola Serial Number	Lg.	Length Spec.	Length Actual	Width 96+0-.18	Height 96+0-.18	Diagonals D1-D2 (.50)	Diagonals D3-D4 (.50)	Diagonals D5-D6 (.50)
1A(before)	10	117.75	117.62	95.88	95.88	.06	.12	0
1A(after)	10	+0-.18	117.62	95.88	95.88	.12	.12	0
1B	20	238.50	238.38	95.94	95.88	.18	.06	.06
1B	20	+0-.25	238.38	95.88	95.94	.06	.12	.06
1C	10	117.75	117.68	95.88	95.94	.12	.25	.12
1C	10	+0-.18	117.62	95.88	95.94	.12	.06	.06
2B	20	238.50	238.38	95.94	95.88	.12	0	0
2B	20	+0-.25	238.38	95.94	95.94	.18	.06	0
1A 1C	20	238.50	238.38	-	-	.06	.12	0
1A 1C	20	+0-.25	238.38	-	-	-	.06	.06
1A 1B 1C	40	480.00 +0-.38	479.75	-	-	-	.06	.06
1A 2B 1C	40		479.68	-	-	-	.12	.38

Table 2 has been tabulated from Brooks & Perkins inspection check sheets to show the basic structural dimensions before and after the static tests. The results indicate that all the gondolas were well within the allowable tolerances at the conclusion of the test program. Refer to Figure 5 for the locations of dimensions.

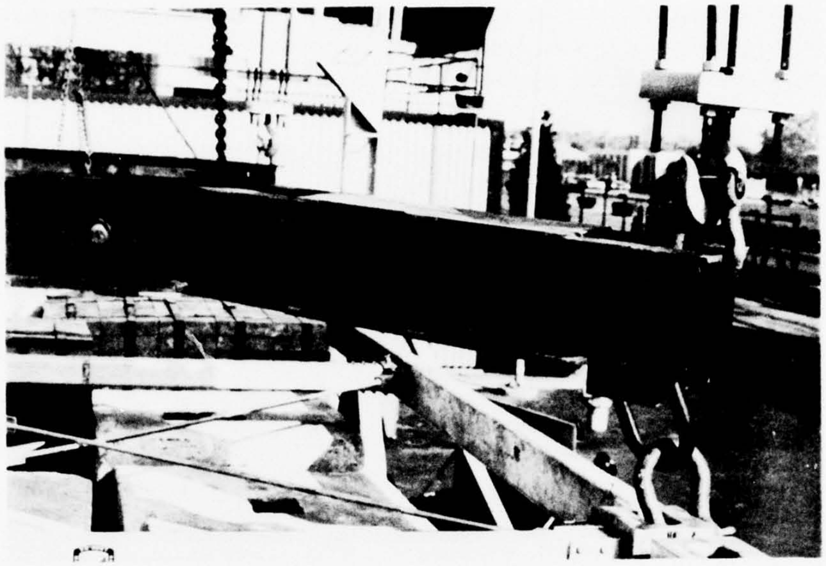


Figure 6. Top Lift Test of the 40-Foot Gondola Showing 30° Single-Point-Lift Setup.

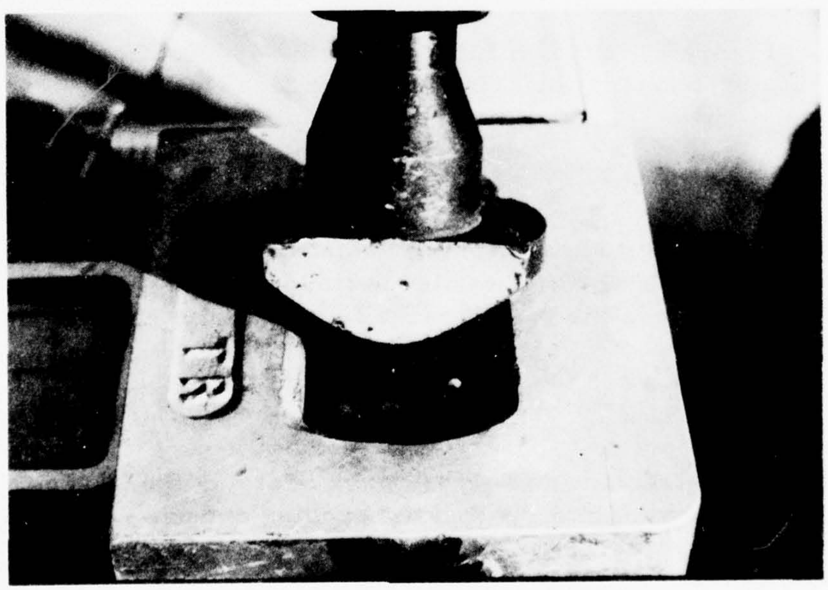


Figure 7. Vertical Loading on Corner Fitting in the Top Lift Test.

BOTTOM LIFT

The 40-foot gondola was loaded to a total gross weight of 124,800 pounds (60,000 pounds times the 2.0 lift factor times the 1.04 asymmetry factor) and lifted by the four bottom corner fittings. Figure 8 shows how the test frame engaged the lower corner side openings.

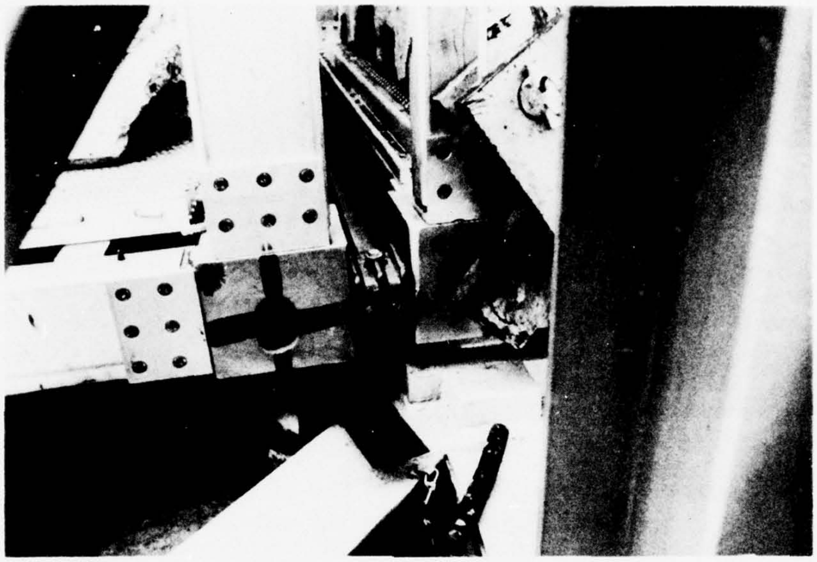


Figure 8. Bottom Lift Test of the 40-Foot Gondola Showing Engagement in the Side Opening and the Lower Coupler.

RACKING

The lateral and longitudinal racking loads were applied to an empty 20-foot gondola by holding the lower corner and applying 18,000 pounds (30,000 pounds times the 0.6g marine factor) to the upper corner as shown in Figure 9.

FORKLIFT

The forklift requirement was simulated by raising the 20-foot gondola, inserting steel beams into the forklift opening and lowering the gondola as shown in Figure 10. The total weight of the setup was 37,500 pounds (30,000 pounds times 1.25g).

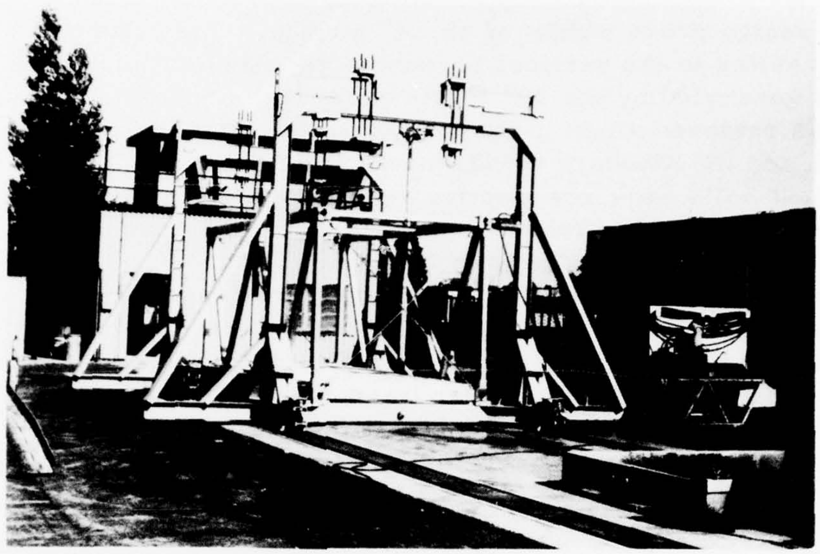


Figure 9. Lateral Racking Test of the 20-Foot Gondola.

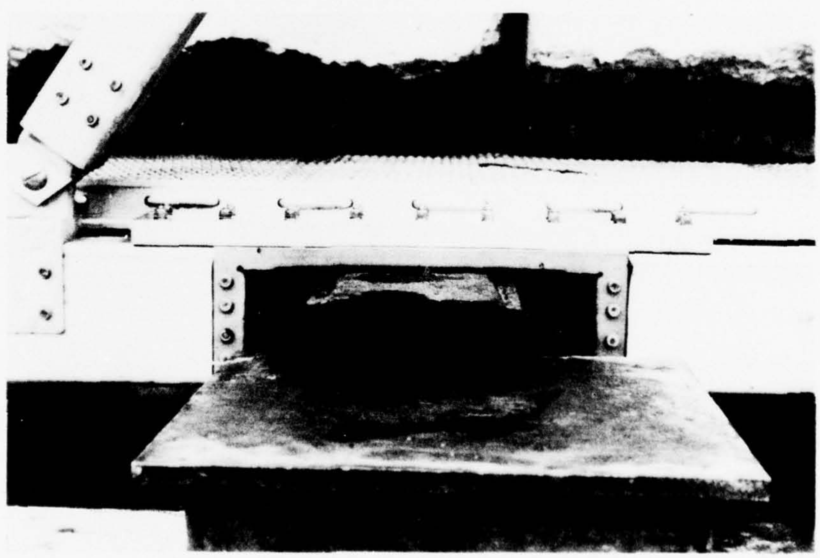


Figure 10. Forklift Test of the 20-Foot Gondola.

DESIGN UPDATE

All tests were completed successfully with exception of the first 40-foot single-point top lift. One of the upper corner fittings of the 20-foot gondola (No. 2A) separated at approximately 160,000 pounds, which represents a design gross weight of 45,248 pounds. The bolts that attached the corner casting to the vertical corner posts failed in tension due to the moment generated by the 30° single-point lift connection. This requirement was removed since it did not represent actual use in the planned system, and the standard twist lock vertical lift was substituted. The attachment bolts were changed for higher strength bolts, and the top lift was performed successfully.

Since the heavy-lift helicopter requirement no longer applies, the gondola systems need only to be compatible with the Container Handling Device (CHD) and be capable of carrying 33,300 pounds.[3] Therefore, the present 20-foot gondola base units or the coupled 10-foot units, rated at 30,000 pounds, may be lifted by either the vertical or the 30° single-point lift. The 40-foot combination is also limited to this weight due to the lifting capability of the CH-54 with the CHD.

All drawings for the 10- and 20-foot units have been revised to incorporate all changes made during fabrication and testing.

CONCLUSIONS

Several points have been established as a result of the fabrication and testing of the gondola system.

1. The designs were capable of being produced without requiring any special tools or manufacturing techniques. The structure used standard-type structural members and hardware.

2. All of the members could be predrilled with the exception of the diagonals, which would probably require some drilling during assembly.

3. The design is capable of being connected together to form either 20- or 40-foot units meeting MH5.1 dimensional requirements.

4. The only design requirement that must be revised is the maximum gross weight limitation (36,199 pounds) imposed on the 40-foot combinations when used with 30° single-point lifts. This load was verified by the static testing and is above the 25,000-pound capability of the CH-54. All other load requirements were verified by the static test program.

5. The standard couplers selected proved to be satisfactory for connecting the gondolas and providing the required strength.

6. The ramps are installed and stowed quickly, and all tierods are also easily removed.

7. The members utilizing 7005 aluminum alloy were capable of being extruded satisfactorily.

8. The gondolas are capable of being acquired and released by the Container Handling Device (CHD).

RECOMMENDATIONS

The following items should be reviewed during the flight test phase and at the conclusion of the program.

1. Study the effects of load size, terrain, and supported and unsupported floor side members on the removal and the installation of the side diagonals.

2. Close attention should be paid to the area where the vertical corner posts are attached to the floor structure for damage by forklifts. These fasteners may require revision to shorten their protrusion on the inside of the gondola.

3. Determine what vibration effect flight has on the tension rods, grating, ramp and wheel chock stowage.

4. Since the 60,000-pound HLH requirements are not valid presently, the design loads, the 40-foot configuration, and the g factors should be reviewed for present helicopter capabilities. Using such a new design criteria would significantly reduce gondola weights.

LIST OF REFERENCES

1. Weber, C., Young, R., DESIGN CONCEPTS FOR HELICOPTER PALLETS AND GONDOLAS, Parsons of California; USAAMRDL Technical Report 74-91, U.S. Army Air Mobility Research and Development Laboratory, Ft. Eustis, Virginia, November, 1974, AD A004013.

2. AMERICAN NATIONAL STANDARD MH5.1-1971, The American Society of Mechanical Engineers, New York, N.Y., 1972.

3. Costa, F., Nutley, W., Seebol, R., Wilson, G., DESIGN, DEVELOPMENT AND LABORATORY TESTING OF A CONCEPTUAL HELICOPTER-TRANSPORTED CONTAINER HANDLING DEVICE, Boeing Vertol Company; USAAMRDL Technical Report 74-40, U.S. Army Air Mobility Research and Development Laboratory, Ft. Eustis, Virginia 23604, May, 1974, AD 783394.

APPENDIX A

Static Test Report No. RD-562, Retest No. RD-600
Miner Enterprises, Inc., Chicago, Illinois

SPECIAL INSTRUCTIONS ON TESTING OF SPECIFIED CONTAINER

Stacking - one corner and one offset.
Racking - one direction only on transverse and longitudinal.
Forklift test - 37,500 pounds gross.
Bottom lift - coupled together as 40-foot unit, 124,800 pounds.
Top lift - coupled together as 40-foot unit, lift 30° angle from top corner castings.

ORDER IN WHICH TESTS WERE CARRIED OUT

1. Dimensional check.
2. Stacking - 20-foot.
3. Racking - transverse.
4. Racking - longitudinal.
5. Forklift test - 20-foot.
6. Bottom lift - 40-foot.
7. Top lift - 40-foot.
8. Retest top lift - 40-foot.

PERSONS WITNESSING CONTAINER TESTS, IN FULL OR ANY PART OF

Conley H. Snow; Brooks & Perkins, Inc.
Charles E. Carlsen: Brooks & Perkins, Inc.
S. G. Riggs; U.S. Army Air Mobility R&D Laboratories.
Miner Enterprises personnel.

GENERAL CONCLUSIONS

All tests were completed and passed in a manner satisfactory to the government inspector witnessing the tests, with one exception, the top lift. (See page 29 for details.)

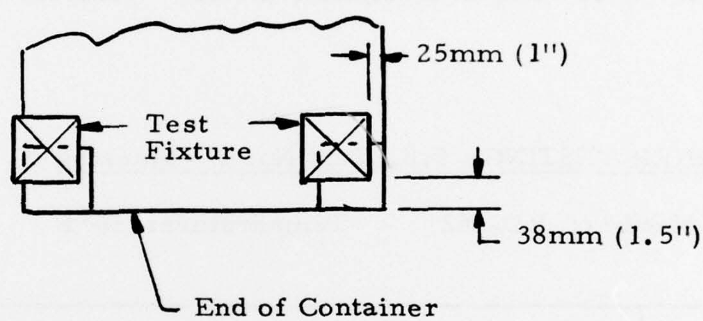
The top lift test was repeated on another 20-foot center unit and was completed satisfactorily. (See page 37 for details.)

CONTAINER TESTING: 5.2, Test No. 2 - Stacking

Project Number: RD-562

Test Procedure:

One corner structure under test has been loaded in compression in three increments of loading. The supports on which the bottom corner castings are located are essentially the same plan dimensions as the corner castings. The fixture used for stacking is the same plan dimensions as the top corner castings. This fixture is located in one eccentric position, 38mm (1.5") off center in the longitudinal direction and 25mm (1.0") off center in the lateral direction for one test on the total container.



CONTAINER TESTING: 5.2, Test No. 2 - Stacking

Project Number: RD-562 Temperature: 50°F Date: 10/18/76

Load	Height Deflection (inches)		
	Before Loading	Load Applied	Load Released (Set)
20,900	0	+0.06	-
45,400	-	+0.12	-
67,500	-	+0.17	+0.05 *

Remarks: *Seal between dissimilar metals - possible reason for set.

CONTAINER TESTING: 5.2, Test No. 2 - Stacking

Project Number: RD-562 Temperature: 50°F Date: 10/18/76

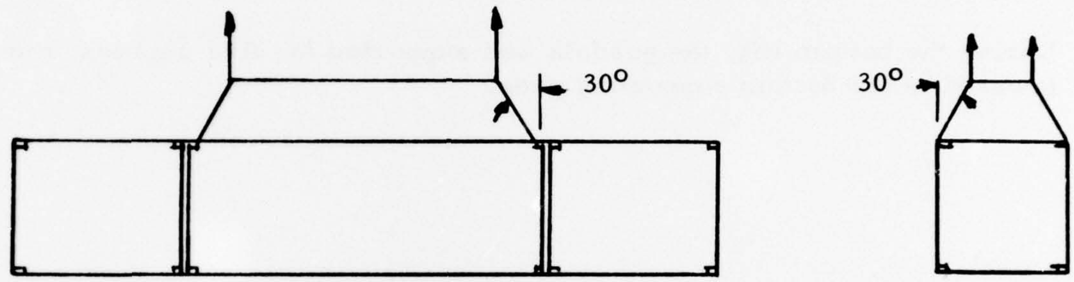
Load	Bow Deflection (inches)					
	Set			End		
	Before Loading	Load Applied	Load Released (Set)	Before Loading	Load Applied	Load Released (Set)
20,900	0	-0.02	-	0	+0.02	-
45,400	-	-0.02	-	-	0	-
67,500	-	0	0	-	0	+0.02

CONTAINER TESTING: 5.3, Test No. 3 - Lifting by the Top Corners

Project Number: RD-562

Test Procedure:

One coupled 40-foot unit was loaded uniformly to a gross weight of 212,160* pounds. The coupled unit was then lifted vertically in such a way that no significant acceleration forces were applied. Shackles were used in the side aperatures of the top corner castings and applied a load at a 30° angle from the vertical with reference to the ends and sides.



Remarks: The 40-foot coupled unit was loaded uniformly to 209,175* pounds gross weight and was lifted vertically. At approximately 160,000 pounds (determined at last sighting of pressure gage) of lifting force, corner casting at corner (C) separated from the corner post. Approximately 3 to 5 minutes later, the corner casting at corner (D) separated in the same manner. Approximately 2 to 3 minutes later, the corner casting at corner (A) separated in the same manner.
Visual inspection was made and it was concluded that the bolts had broken in tension.
No measurements were made because of the failure.

* (weight is ± 1%)

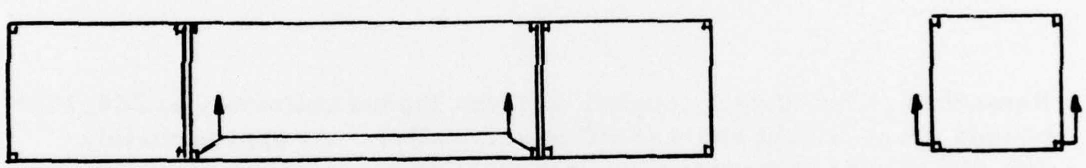
CONTAINER TESTING: 5.4, Test No. 4 - Lifting from the Bottom

Project Number: RD-562

Test Procedure:

One coupled 40-foot unit was loaded uniformly to a gross weight of 124,800* pounds. The coupled unit was then lifted vertically in such a way that no significant acceleration forces were applied. A simulated lifting sling attached to the side aperatures of the bottom corner castings was used for lifting the 40-foot unit vertically. The slings were attached to the 20-foot section of the 40-foot unit. All lifting arrangements were kept clear of the sides. The approximate lifting for the line of force was 30° to the horizontal.

During the bottom lift, the gondola was supported for five minutes, then lowered to the bottom supporting pads.



Remarks: * (weight is ± 1%)

CONTAINER TESTING: 5.4, Test No. 4 - Lifting from the Bottom

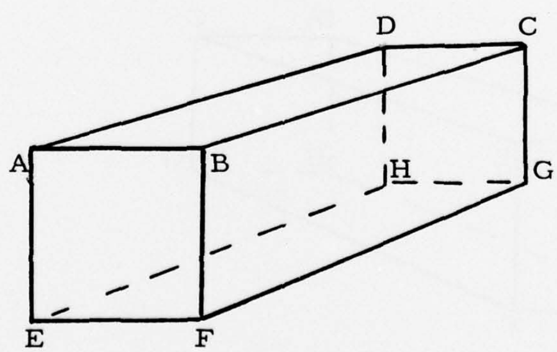
Project Number: RD-562　　Temperature: 42°F　　Date: 10/20/76
Load: 124,800 pounds

Dimensions in inches.

	Side	South 10' Section	Center 20' Section	North 10' Section
Datum Before	-FG-	0	0	0
Lifting	-EH-	0	0	0
Deflection at sidewall when	-FG-	-0.09	+0.22	+0.03
suspended	-EH-	+0.02	+0.34	-0.05
Datum After	-FG-	+0.03	0	0
Lifting (Set)	-EH-	0	+0.06	+0.03

Remarks: (+) beam bows down
(-) beam bows up

*actual weight was 124,180 pounds ± 1%



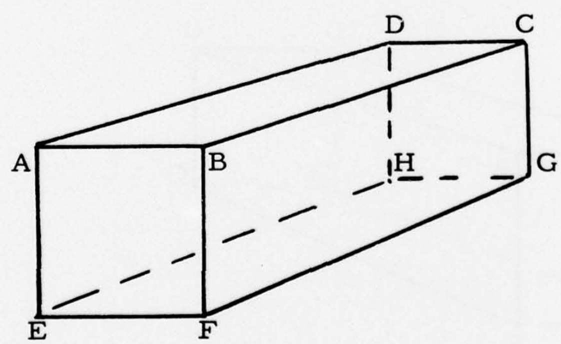
CONTAINER TESTING: 5.4, Test No. 4 - Lifting from the Bottom

Project Number: RD-562 Temperature: 42°F Date: 10/20/76
Load: 124,800 pounds
Dimensions in inches.

	Side	Separation of 10' from 20'		Expansion of Top Couplers			
		South 10'	North 10'	South Top @ East	South Top @ West	North Top @ East	North Top @ West
Datum Before Lifting	-FG-	0	0	0	0	0	0
	-EH-	0	0				
Deflection at sidewall when suspended	-FG-	-0.84	-0.33	+0.18	+0.27	+0.22	+0.16
	-EH-	-0.83	-0.39				
Datum After Lifting	-FG-	-	-	+0.05	+0.03	+0.03	-0.02
	-EH-	-	-				

(+) expansion
(-) contraction

Remarks:

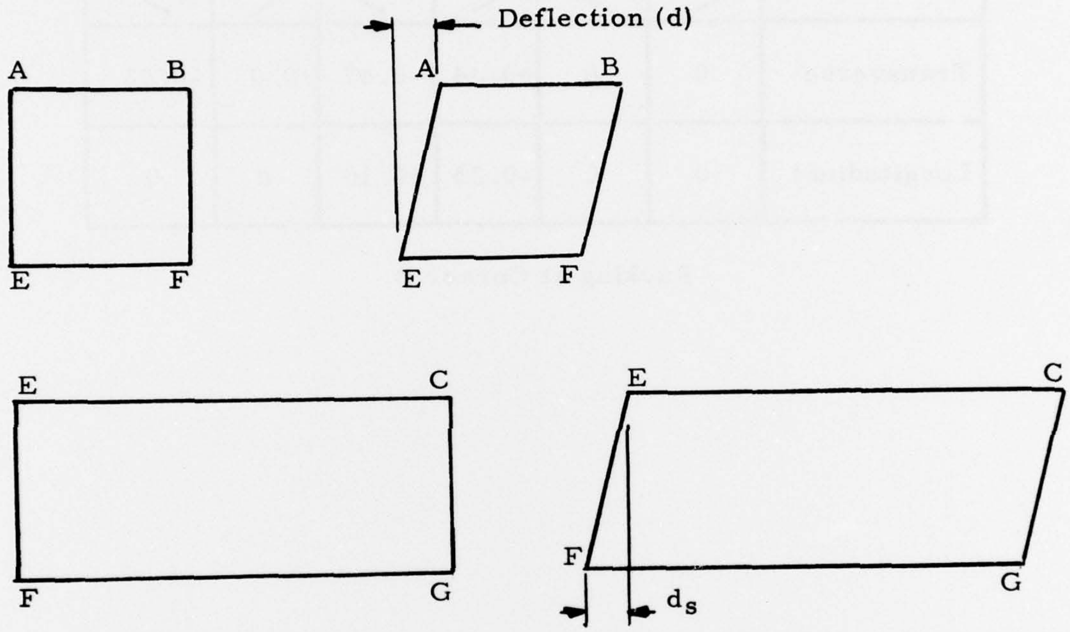


CONTAINER TESTING: 5.5, Test No. 5 - Racking

Project Number: RD-562

Test Procedure:

The container was secured to rigid anchor points at all four bottom corner castings. A horizontal force was applied to one top corner casting at one end in a transverse direction. Both ends were tested in this manner. A force was applied to one top corner casting on one side in a longitudinal direction.



Deflection under load is found by using the following formula:

$$d = \frac{2(\Delta_1 + \Delta_2)\,(h^2 + w^2)^{1/2}}{4w}$$

Δ_1 = change in larger diagonal

$$d_s = \frac{2(\Delta_1 + \Delta_2)\,(h^2 + l^2)^{1/2}}{4l}$$

Δ_2 = change in smaller diagonal

CONTAINER TESTING: 5.5, Test No. 5 - Racking

Project Number: RD-562 Temperature: 50°F Date: 10/18/76
Load in transverse direction: 18,000 pounds
Load in longitudinal direction: 18,000 pounds (1636 psi)

	Change in Diagonals (inches)					
	Before Load		During Load		After Load	
	\	/	\	/	\	/
Transverse	0	0	+0.44	-0.47	+0.03	-0.03
Longitudinal	0	0	-0.25	+0.16	0	0

Racking at Corner B

CONTAINER TESTING: 5.6, Test No. 6 - Forklift

Project Number: RD-562

Test Procedure:

One 20-foot gondola was loaded uniformly to a gross weight of 37,500 pounds. The 20-foot gondola was then lifted vertically from its four top corner castings. Two bars were placed in the forklift pockets and supported at each end (four supports). The 20-foot gondola was lowered down until all the weight rested on just the two horizontal bars.

During the forklift test, the 20-foot gondola was supported for 5 minutes, then lifted vertically to remove the bars and supports, then lowered to the bottom supporting pads.

CONTAINER TESTING: 5.6, Test No. 6 - Forklift

Project Number: RD-562 Temperature: 52°F Date: 10/20/76
Load: 37,500 pounds
Dimensions in inches.

	Side	Bottom Rails Fork Pockets	*
Datum Before Lifting	-FG-	0	0
	-EH-	0	0
Deflection at side-wall when suspended	-FG-	0.61	0.05
	-EH-	0.55	0.02
Datum After Lifting	-FG-	0	0
	-EH-	0	0

Remarks:

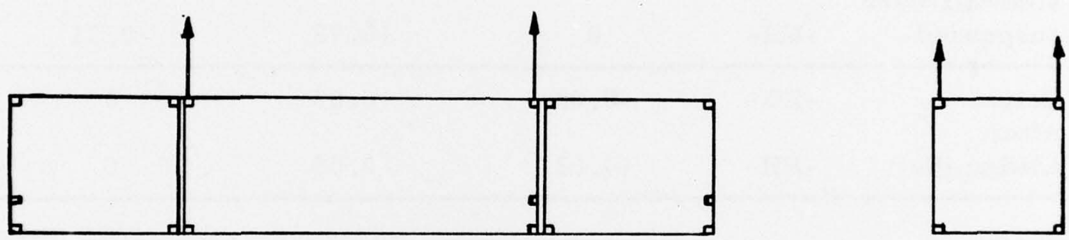
*During lifting procedure, when the horizontal bars for the forklift test were being inserted, measurements were taken as if a top lift with the same load (as the forklift test) was being done.

CONTAINER TESTING: 5.3, Test No. 3 - Lifting by the Top Corners

Project Number: RD-600 (retest)

Test Procedure:

One coupled 40-foot unit was loaded uniformly to a gross weight of 212,160* pounds. The coupled unit was then lifted vertically in such a way that no significant acceleration forces were applied. Twist locks were used in the top aperatures of the top corner castings. The lift was held for 8 minutes before lowering.



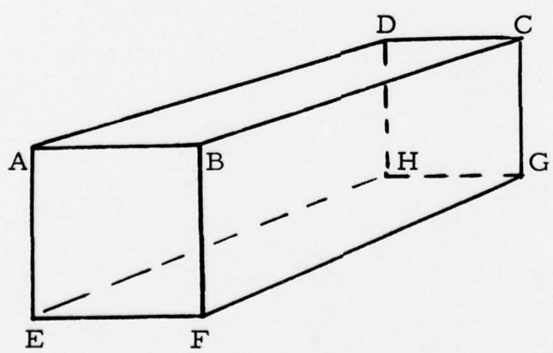
*(weight is +1/2%)

CONTAINER TESTING: 5.3, Test No. 3 - Lifting from the Top Corners

Project Number: RD-600 Temperature: $40^{o}F$ Date: 2/24/77
Load: 212,160 pounds
Dimensions in inches.

	Side	South 10' Section	Center 20' Section	North 10' Section
Datum Before Loading	-FG-	0	0	0
	-EH-	0	0	0
Deflection at sidewall when suspended	-FG-	-0.17	+0.69	-0.25
	-EH-	0	+0.78	-0.31
Datum After Lifting (Set)	-FG-	+0.02	+0.03	0
	-EH-	+0.02	-0.05	0

Remarks: (+) beam bows down
(-) beam bows up



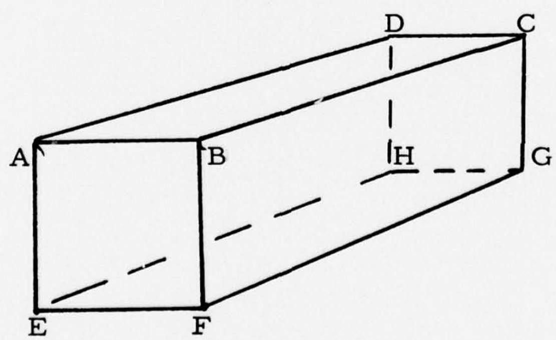
CONTAINER TESTING: 5.3, Test No. 3 - Lifting from the Top Corners

Project Number: RD-600   Temperature: 40°F   Date: 2/24/77
Load: 212,160 pounds
Dimensions in inches.

	Side	Separation of 10' from 20'		Expansion of Top Couplers			
		South 10'	North 10'	South Top @ East	South Top @ West	North Top @ East	North Top @ West
Datum Before Lifting	-FG-	0	0	0	0	0	0
	-EH-	0	0				
Deflection at side-wall when suspended	-FG-	-1.03	-0.78	+0.21	+0.31	+0.31	+0.23
	-EH-	-0.81	-0.94				
Datum After Lifting	-FG-	-	-	0	0	0	0
	-EH-	-	-				

(+) expansion
(-) contraction

Remarks:



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